Versuch Nr. 24 / Experiment Nr. 24 (MOSFET)

The Metal-Oxide-Semiconductor (MOS) junction and the MOS-Field Effect Transistor (MOSFET)

The aim of this experiment is to investigate the basic physical properties of the MOS junction, the basic building block of the field effect transistor (MOSFET) used in almost all areas of Silicon microelectronics. Initially the experiment focuses on capacitance-voltage (C-V) measurements of a 2-terminal MOS structure. Analysis of the recorded C-V characteristics provide information about the physics of the system (accumulation, depletion and inversion modes) and enables determination of the oxide thickness (d_{ox}), the doping type of the semiconductor (n- or p-type) and the trap level concentration (N). The influence of above bandgap illumination on the C-V characteristics will then studied and explained. The experiment then will turn to the properties of a real 3-terminal MOSFET *transistor* structure. Using C-V and conductivity-voltage (σ-V) studies, the threshold voltage (V_t), mobility of charge carriers in the inversion layer channel (μ_{eff}), carrier density in the channel (n_s) and the so-called field effect mobility (μ_{FE}) will be determined.

1) Experimental steps

- Build and understand the set-up for the measurement of differential capacitance.
- Calibrate the measurement set-up
- Measure the capacitance of a MOS structure as a function of the gate voltage at various frequencies with and without illumination.
- Determine d_{ox}, N and explain the influence of light.
- Build and understand the set-up for the σ-V measurements on the MOSFET.
- Measure the input and output characteristics of the transistor at room temperature and 77K.
- Determine μ_{eff}, n_s and μ_{FE} and calculate the carrier scattering time in the device.

2) Essential physical concepts

Bandgaps in solids, semiconductors, insulators, metals, doping, intrinsic and extrinsic semiconductors, Fermi-energy, surface potential, depletion region, inversion layer, accumulation layer, space charge region, carrier mobility, charge scattering in transport.

3) Apparatus and measurement techniques

Frequency generator, oscilloscope, programmable voltage source, computer & DAQ card for measurement, multi-meter, calibration capacitance decade, MOS measurement cell, sample holder for liquid nitrogen, lock-in amplifier and principle of operation.

4) Comments

The experiment will take around 5 hours to complete, please bring laptop for plotting data and memory stick to copy data for analysis. Always handle cryogenic liquids with extreme care, wearing gloves and safety goggles.